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INNOVATION

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NASA-sponsored Bioreactor research on Earth and during long-term space missions aboard the *Mir* space station is the beginning of a new frontier in cell science—an opportunity to contribute to public health and to better understand normal breast cell and cancerous breast tissue development.

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COMMERCIAL DEVELOPMENT MISSION UPDATE

Date*	Flight	Payload	Sponsor/Coordinator
1/99	STS-93	AEROGEL	Marshall Space Flight Center
	AXAF	Commercial Generic Bioprocessing Apparatus-04**	BioServe Space Technologies

Note: Sortie flights beyond STS-95, and Space Station Operations, under review at this time.

* As of November 1998.
** In combination with National Institutes of Health payload NIH-B1 in support of Life Sciences Division requirements.
Key STS—Space Transportation System, AXAF—Advanced X-ray Astrophysics Facility

Microgravity: A Medical Research and Treatment Tool

By Dr. Neal R. Pellis
Manager, Biotechnology Cell Science Program
Johnson Space Center

BIOMEDICAL RESEARCHERS NATIONWIDE ARE undertaking pioneering studies that may provide new knowledge and technologies that bring exciting advances in research and the treatment of disease, by engineering human tissues from individual cells using the microgravity of space and a unique technology developed by NASA.

NASA's rotating, cylindrical Bioreactor, relatively new to cell science, is an application of microgravity that can be used on Earth as well as in space. The potential for contributions is presently emerging, and researchers are producing exciting new results by creating three-dimensional cell cultures that are significantly more similar to tissues found in the human body.

Much valuable research has been obtained from the traditional research method used by scientists for more than 100 years—culturing mammalian cells using dishes in which cells sediment to the bottom surface, producing a thin sheet of cells—but this has limited application in modeling functional human tissue. The cells are not arranged as they are in the body.

The NASA ground-based Bioreactor is a horizontally rotating cylinder that simulates microgravity. The fluid culture medium filling the cylinder rotates at the same rate as the cylinder, resulting in continuous suspension of the cells. Conditions in the Bioreactor are very conducive to engineering tissues from individual cells and for simulating microgravity on the ground, where the device is suitable for the proliferation of small (<0.5 inch) tissue specimens. The space Bioreactor is substantially more complex than the ground-based counterpart because it must operate autonomously and function flawlessly for extended duration in space vehicles. It is the basis on which more sophisticated units will be designed for the International Space Station, a setting in which long-duration experiments are critical to the growth of this science and to its inevitable application in science and medicine.

The microgravity environment of space flight supports tissue engineering and may provide the necessary strategy to grow larger tissue specimens. Cancer cells cultured for five days aboard STS-70 produced results that clearly showed that cell assembly in microgravity was more than 10 times the size of the control culture of a ground-based Bioreactor. In a longer duration study, STS-79 carried cartilage cells in synthetic scaffolds to be cultured on *Mir* for more than 130 days. Tissue in the flight Bioreactor showed some characteristics that are indicative of microgravity and may be suitable for clinical and research applications.

Tissue engineering research, using NASA's Bioreactor, can contribute to reducing costs and developing treatment alternatives. Many of these areas require both ground-based and space experiments. Microgravity offers the prospect of advancing research in several critical areas that can have significant impact in science and medicine. Using the NASA-developed space and ground-based Bioreactors for growing human tissues from individual cells, tissues could be developed for use in medical transplantations to replace defective organs and tissues. Producing models of human disease could help in the development of novel drugs for prevention and treatment, strategies to reengineer defective tissues and new hypotheses for the emergence of diseases such as cancer.

The unique attribute of simulated and true microgravity, using the NASA Bioreactor, has begun to produce accomplishments to contribute to knowledge for improved health care. For example, living cells from human ovarian and breast tumors are being successfully cultured and grown into masses that resemble the original tumor to further understand growth and spreading factors. Ovarian and breast cancers are among the leading causes of cancer deaths among women. Colon cancer tumors also are being produced. The Bioreactor also is used to produce models of human prostate cancer. NASA tissue culture research has given the medical community a powerful new tool to study how these cancerous tissues form. Human cartilage is also being attempted in masses large enough for implant studies. Evaluating the effects of drugs also is a benefit. Kidney tissue cultured in the NASA Bioreactor helps evaluate renal drug toxicity, while the assembly and growth of cardiac muscle tissues grown in the NASA Bioreactor are used to study the effects of new drugs on muscle diseases. Cells respond to simulated and true microgravity by making novel adaptation changes that could in turn give us new insights to cellular processes and establish a cellular basis to the human response to microgravity and the space environment.

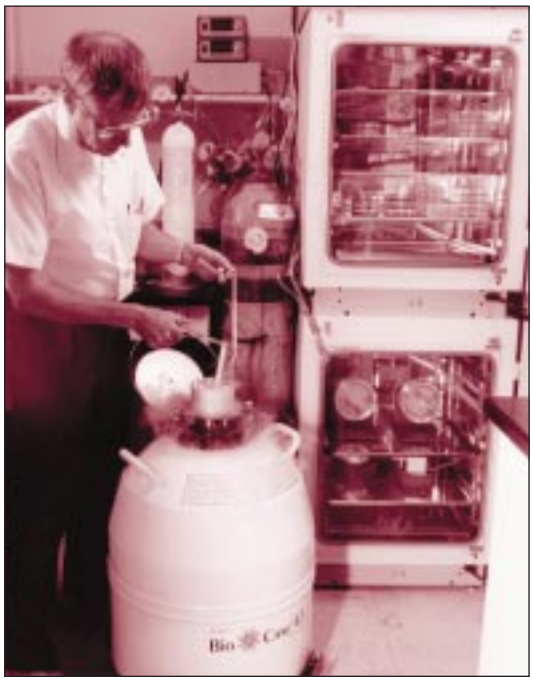
NASA is confident that the disturbance microgravity invokes on cells, and the resultant changes to the cell, will lead to new discoveries in the cell and advance understanding of biological function in the space environment for use on Earth and in space.

Space Bioreactor Helps Understand Breast Cancer

A SPECIAL INCUBATOR DESIGNED TO GROW tissue samples in space is being applied on Earth to help understand how breast cancer works and how it might be controlled. Ground-based scientists are using NASA Bioreactors to culture breast cells and learn what controls the growth of both healthy and malignant breast tissues. Their findings could affect health care for women not only on Earth, but also on missions to Mars.

"We know that many things—radiation, certain chemicals, genetic makeup—can contribute to the cause of breast cancer," said Dr. Robert Richmond, director of the recently created Radiation and Cell Biology Laboratory at NASA's Marshall Space Flight Center in Huntsville, Alabama. Richmond is also a research associate professor of medicine at the Dartmouth Medical School in Hanover, New Hampshire.

"We are culturing noncancerous mammary cells, hoping to learn what guides their growth and how we might use that knowledge to thwart malignancies before they are created," Richmond added. "The type of mammary cells we are growing comes from an individual susceptible to breast cancer, and that susceptibility is likely driven by damage caused by ionizing radiation. Space exploration will involve slightly increased exposures of crew members to radiation, so what we learn from these cells could help justify methods of female crew selection, and help manage breast cancer in the national population at the same time."



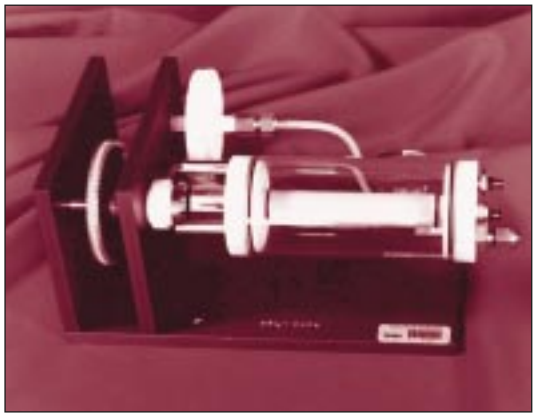
Dr. Robert Richmond extracts breast cell tissue from one of two liquid nitrogen dewars. (Photo by Dennis Olive, NASA/Marshall Space Flight Center)

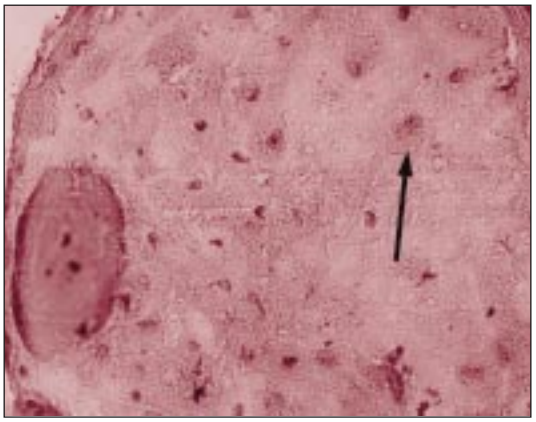
Cancer research is typically a collaborative and interdisciplinary effort. Richmond was connected with a breast cancer-susceptible donor of the mammary tissue now used in his laboratory by Dr. Mike Swift of the Medical College of New York, Hawthorne. Drs. Olive Pettengill (Pathology Department of the Dartmouth Medical School) and Martha Stampfer (Lawrence Berkeley National Laboratory) helped him select cells from this cancer-susceptible breast tissue. Within NASA, Richmond also interacts with Dr. Jeanne Becker, an associate professor at the University of South Florida College of Medicine in Tampa, and with investigators in the Biotechnology Cell Science Program at NASA's Johnson Space Center in Houston, home of the NASA Bioreactor.

For many people, culturing cells means placing some small number into nutrient media in a dish or a tube and letting them grow, resulting in pancake shapes that offer limited insight. Without a proper three-dimensional assembly, epithelial cells (the basic cells that differentiate tissue into specific organ functions) lack the proper clues for growing into the variety of cells that make up breast tissue.

Cells self-associate in the body, meaning that replication involves associating with the proper connections in the surrounding environment (the body) for proper growth clues to naturally form. However, gravity's effects limit studying cell growth outside the body because, in an Earth gravity environment, the cells do not easily self-associate to grow naturally. A culture environment must closely, if not exactly, simulate tissue assembly in the body to enable the cells with the proper growth clues.

To solve the problem, in the 1980s, NASA developed the Bioreactor, a clear, can-like rotating vessel with a membrane for gas exchange that allows nutrients in and carbon dioxide and wastes out. As the Bioreactor turns, the cells continually fall through the medium yet never hit bottom, thus promoting the self-association of a proper growth environment. The cells then form clusters and grow and differentiate as they would in the body.





(Left) One of several Bioreactors used by Dr. Richmond in his research. (Photo by Dennis Olive, NASA/Marshall Space Flight Center)

(Right) A cross section of a construct, grown from surgical specimens of breast cancer and stained for microscopic examination, reveals areas of tumor cells dispersed throughout the nonepithelial cell background. The arrow denotes the foci of breast cancer cells. (Photo by Dr. Jeanne Becker, University of South Florida)

Therefore, Richmond and Becker are using NASA Bioreactors to fool mammary cells into thinking they are in a normal environment and thus culture them into larger assemblies whose natural growth can be studied. At Marshall Space Flight Center, Richmond has established a research program using a unique collection of healthy breast cells that contain a significant genetic weakness toward developing cancer. Becker, in collaboration with co-workers at Johnson Space Center, has grown primary breast cancer cells (obtained directly from different surgical specimens) into masses that resemble the original tumor. She hopes to further our understanding of the factors important in the growth and spread of tumors.

"We have grown noncancerous human breast cells in the NASA Bioreactor," Richmond said. "Our observations suggest there is much to learn, and value to be gained, from the study of their tissue-equivalent growth."

The culturing of primary breast cancer cells for long periods is rarely achieved in standard tissue culture dishes. With tumor cells from 27 different breast cancer patients, Becker could get only five specimens to grow enough to fill the dish. None of the five could then be expanded further when passed to new dishes. In contrast, however, tumor samples from another five breast cancer patients grew successfully for long periods of time as three-dimensional co-cultures in the NASA Bioreactor.

These primary breast tumor cell constructs were grown successfully for up to three months, and the cancerous fraction increased. These constructs grew up to three millimeters in diameter, at which point they were removed for analysis and thus prevented from additional growth. Eventually, in this Earth condition, the Bioreactor cell clusters become too large to fall slowly, and research has to be continued in the true weightlessness of space.

The information relating to the patient-derived breast cancer constructs grown in the Bioreactor by Becker and co-workers at Johnson Space Center suggests that this model simulates events that occur as breast tumors progress within the body. This line of research therefore offers potential for increasing knowledge on the basic biology of human breast cancer. For more immediate application, this research also provides, for the first time, an opportunity to test breast cancer therapies on a patient's cancer cells in culture before extending that therapy to the patient him- or herself.

With the healthy cells, Richmond is developing a normal breast tissue-equivalent model, a scientific description of how healthy breast tissue grows. A routine capability to model patient-specific breast cancer then could allow for testing and developing realistic therapies. For example, hormonal therapy is an important treatment option for approximately a third of previously untreated breast cancer patients. It is well known that breast tissue responds to estrogens. However, normal human mammary epithelial cells in a standard two-dimensional culture dish do not demonstrate any estrogenic response.

Richmond plans experiments that will determine whether three-dimensional constructs of normal breast tissue in the Bioreactor will respond to estrogen. If so, then Bioreactors could be used to tailor hormonal therapies that more closely match what will stop the growth of cancer cells, with minimal side effects for the patient.

To begin this research, Richmond established a cell repository from noncancerous breast tissue donated by a young woman carrying a single defective

DODGING A BULLET

In addition to bringing the space Bioreactor to bear on terrestrial health issues, NASA is also concerned about ionizing radiation—an issue for the Human Exploration and Development of Space Enterprise. Ionizing radiation actually has two components: photons (x-rays and gamma rays) and particles (naked atomic nuclei blasted out from stars and supernovas). "Ionizing" means that the radiation can energize electrons to break away from atoms. Such ionization in the nucleus of a cell can cause genetic damage that promotes the formation of cancer.

Space radiation is of little risk to us on the ground. Earth's atmosphere protects us on the surface from the great majority of space radiation, and Earth's magnetic field shields space crews in low orbits from all but the most energetic particles. Outside the magnetic field, however, the exposure and risk are greater. The exact amount of damage caused by space radiation varies with the length of the trip, the type of shielding used, and the makeup of solar and galactic radiations.

At this time, the radiation damage for a trip to Mars is predicted to provide an approximately lifetime cancer risk for 30-year-old males of about 28 percent, as compared to 20 percent on Earth. This is unacceptably high, and scientists are trying to reduce the risk to about 23 percent. Because the radiation cancer risk to women is projected to be substantially greater, largely as breast and ovarian cancer, mission planners lean toward all-male crews.

It is important to note that scientists talk of risk, not of absolute predictions. Risk factors are applied to groups of people, and they vary greatly from one individual to another because several steps are required for the final development of cancer. It is not possible to know exactly where an individual might be in this chain. Only the average outcome of any normal population can be used to predict risk factors.

As the genetic controls of cancer development become better understood, the "normal population" used for predicting cancer risk factors will also become better defined. "Normal" now means "apparently healthy." However, the many genetic steps leading to cancer can be invisible in a "normal" person. The phrase "cancer susceptibility" frequently mentioned these days indicates a genetic predisposition to cancer.

Breast cancer is associated in part with defects in the BRCA1, BRCA2, and ATM genes. Damage in both of the ATM genes, for example, sets a course for the expression of a devastating clinical syndrome called ataxia-telangiectasia, or A-T, which includes an approximately 100-fold increased risk of cancer. On the other hand, studies by Dr. Mike Swift and co-workers have shown that when only one ATM gene is damaged (called A-T heterozygous), then a woman has about a five-fold increased risk of cancer, despite the fact that she appears clinically normal.

Furthermore, scientists suspect that radiation damage is the principal initiator of increased breast cancer susceptibility in women with one defective ATM gene. It would seem prudent, therefore, to consider identifying A-T heterozygous women who might otherwise be selected for extended living within the space environment and thus not expose them to conditions that would further increase their risk of breast cancer.

ATM gene. The debilitating syndrome ataxia-telangiectasia (A-T) results when both of the two ATM genes normally present in the body's cells become defective. These A-T individuals have about a 100-fold increased risk of all cancers plus other serious problems. Women carrying only one defective ATM gene are clinically normal, but have about a five-fold increased risk, or susceptibility, to breast cancer.

To reduce her breast cancer risk to near zero, the donor elected to have a double mastectomy. Her breast tissues now reside in a cell bank as perfectly matched cell types, preserved in liquid nitrogen, which will allow experimental results of today to be compared with experimental results obtained for many years to come.

In the Bioreactor, these cells will grow in normal fashion because they are normal except for the single defective ATM gene. Once the normal tissue-equivalent model is defined, then these same cells can be manipulated to mimic the stages of breast cancer formation, and the model-related differences can be evaluated. A normal tissue-equivalent model would thus hopefully promote the understanding of the creation of breast cancer and, eventually, allow for the development of therapies tailored to the individual patient.

For more information, contact Dr. Robert Richmond at Marshall Space Flight Center. 256/544-3418, *Robert.Richmond@msfc.nasa.gov* Please mention you read about it in *Innovation.*

Low Gravity Boosts Computerized Casting

RESEARCH IN LOW GRAVITY HAS TAKEN AN important step toward making metal products used in homes, automobiles and aircraft less expensive, safer and more durable. Auburn University in Auburn, Alabama, and industry are partnering with NASA to develop the first accurate computer model predictions of molten metals and molding materials used in a manufacturing process called casting. Cast alloy parts are formed by mixing and pouring melted metals into a mold.

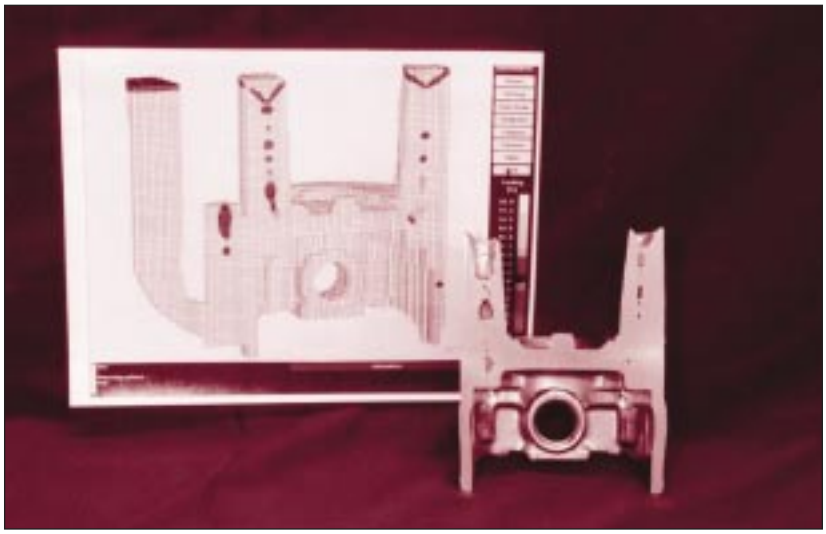
The first commercial use of the new computer information is being made by Howmet Industries of Whitehall, Michigan, to more precisely design and cast aircraft turbine blades. In a similar activity, Ford Motor Company's casting plant in Cleveland, Ohio, is using the information developed by the new computer models to improve the casting process of automobile and light truck engine blocks.

"We're doing the long-range research that industry really needs to improve its final products," said Dr. Tony Overfelt, director of the Solidification Design Center at Auburn University. "We're benefiting the American public—those who pay for the research and use the products."

Cast metal parts are used in 90 percent of all durable goods, such as washing machines, refrigerators, stoves, lawn mowers, cars, boats and aircraft. Sales of cast parts in the United States alone total $25 billion to $30 billion a year, according to the American Foundrymen's Society in Des Plaines, Illinois.

"The NASA and Auburn University-led research project on turbine blade castings has enhanced our capabilities, helped us realize a cost savings and accelerated the development cycle for rocket hardware," said Dr. Thomas Tom, director of advanced technology for Howmet. "Partnering with NASA offers unique research opportunities to improve methods of production used in the foundry industry to enhance the quality of castings," said American Foundrymen's Society director of research, Dr. Joe Santner. He added, "Advanced research into new processes makes casting more affordable, reliable and expands their utility."

Besides the American Foundrymen's Society, three companies from industry participated in the Auburn University-led casting research consortium. These are Anter Corp. in Pittsburgh, Pennsylvania, Thermophysical Properties Research Laboratory, Inc., in West Lafayette, Indiana, and PCC Airfoils Inc. in Beachwood, Ohio.



A computer-generated model of ground-based casting using precise data can only be gathered from space experiments that provide the absence of impurity contamination and buoyancy convection effects.

High-temperature metal alloy parts for the aerospace and auto industry can make aircraft and vehicles stronger, lighter and more efficient, but casting typically requires three to four years to develop an effective process. "We started with experiments on the ground," Overfelt said. "Then we went aboard a NASA KC-135 aircraft flying an arc pattern in low gravity to refine our research. Our goal," he added, "is to continue to produce accurate measurements for all the alloys used by the casting industry. This information can be used by American manufacturers to standardize metal-mixing 'recipes' and to compete more effectively in the worldwide market."

Auburn University is one of NASA's ten Commercial Space Centers. These centers serve as a focal point for NASA partnerships with industry and universities, encouraging unique space-related research opportunities to develop new products and services. The Space Products Development Office of the Microgravity Research Program at Marshall Space Flight Center in Huntsville, Alabama, manages NASA's Commercial Space Center program.

For more information, contact Rose Allen at Marshall Space Flight Center's Space Products Development Office. 256/544-0117, 256/544-7710, *Rosalie.W.Allen@msfc.nasa.gov* Or contact Tony Overfelt at Auburn University. 334-844-5940. Please mention you read about it *Innovation.*

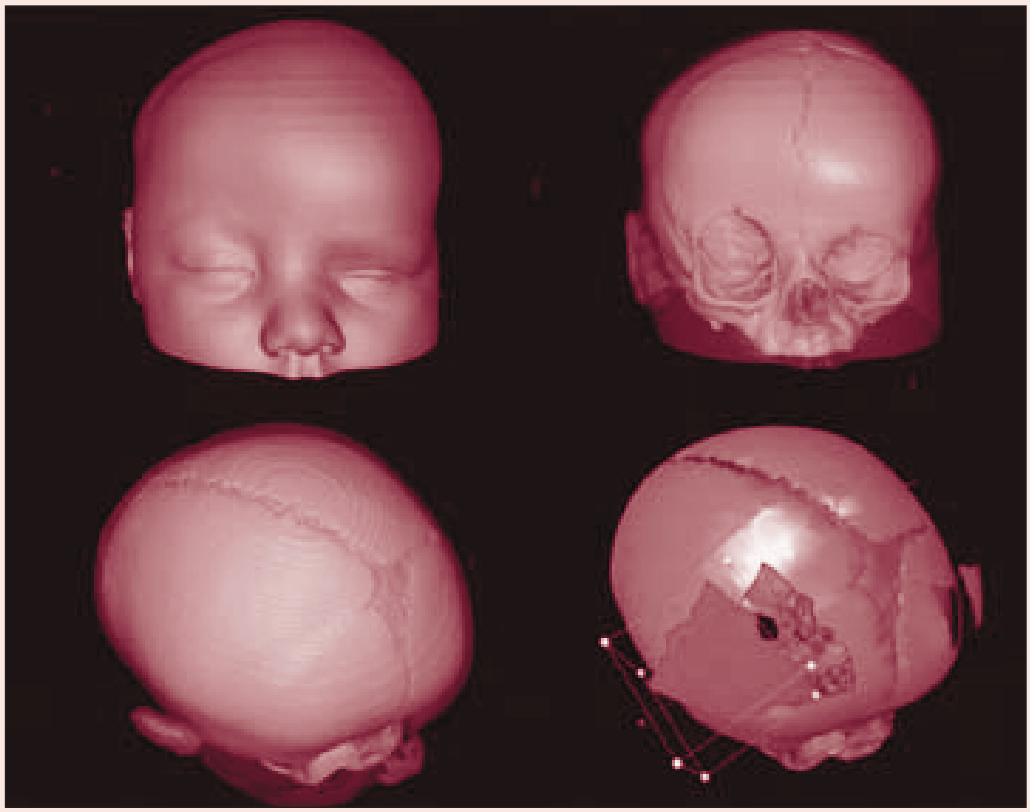
PARTNERSHIP TO DIAGNOSE "VIRTUAL HOSPITAL"

NASA's Ames Research Center, Moffett Field, California, and Salinas Valley Memorial Hospital recently signed a Space Act Agreement to be partners in the implementation of state-of-the-art information technologies to develop a "virtual hospital" in 1999. Ames is NASA's Center of Excellence for Information Technology and has strong three-dimensional imaging capabilities in its Center for Bioinformatics. Under the terms of the agreement, Ames will establish a workstation at the hospital capable of transmitting data and receiving three-dimensional images of the human body. The hospital will transmit diagnostic data to Ames over NASA's Research and Education Network (NREN). Hospital medical teams will be able to evaluate and manipulate the three-dimensional images over NREN.

When the virtual hospital demonstration begins operations in 1999, Salinas Valley Memorial Hospital physicians will be able to provide feedback to NASA regarding image quality and network efficiency. A virtual hospital is defined as a health care facility with technology to transmit and manipulate electronically three-dimensional high-fidelity resolute images in real time.

Future plans call for Ames and the hospital to work cooperatively with Stanford University Medical Center and the Cleveland Clinic in exploring the possibility of implementing the virtual hospital technology to remote areas around the world and eventually in space. The three hospitals, all major cardiac centers, would use high-speed Internet links to exchange images and information. The virtual hospital would also enable doctors to conduct cooperative training exercises and be able to perform "dry run" surgeries using three-dimensional images.

For more information, contact Dr. Muriel Ross at Ames Research Center. 650/604-4804, 650/604-3954, *mross@mail.arc.nasa.gov*
Please mention you read about it in *Innovation.*



This image is a sample of technology envisioned for the "virtual hospital" concept.

Hazardous Waste Recycled to Commercial Fertilizer

A JOINT EFFORT BETWEEN KENNEDY SPACE Center and I-NET Inc. (the engineering support contractor, now held by Dynacs Engineering Co.) has resulted in an innovative control system and process that recovers and converts unused rocket propellant oxidizer into a useful fertilizer. The Improved Nitrogen Oxide (NO_X) Scrubber is projected to save Kennedy about $80,000 per year in waste disposal and fertilizer costs. The scrubber also provides safety and environmental improvements by reducing workers' risk of exposure to toxic NO_X emissions by a factor of 10 to 200.

Developed from a concept by Kennedy engineer Dr. Dale Lueck and designed by Dr. Clyde Parrish of I-NET, the innovation eliminates Kennedy's second largest waste stream and associated waste disposal costs. "The resulting fertilizer replaces 10 percent of the potassium nitrate fertilizer purchased at Kennedy and does not add significantly to the raw material costs," Parrish said, adding that the "overall cost savings at Kennedy is approximately $80,000 per year."

Kennedy plans to install the system at several scrubbers. The control system could also be used at Vandenberg Air Force Base in California, White Sands Test Facility in New Mexico, Cape Canaveral Air Station in Florida, Titan Launch Complex 40 or any location where the quantity of oxidizer requires a scrubber. Any commercial industries in which NO_X is released, such as metal finishing operations, could also use the technology. NASA has a pending patent application for this technology.

A Space Shuttle steering rocket uses nitrogen tetroxide as its propellant. When the toxic oxidizer (nitrogen tetroxide) is transferred from storage tanks into rockets, or vice versa, the nitrogen dioxide vapor is captured in a device called a scrubber to prevent it from venting to the air.

A control system was developed to convert the hazardous NO_X scrubber liquor to a useful, beneficial and marketable fertilizer. The chemical process captures nitrogen tetroxide in water, in which hydrogen peroxide oxidizes the resulting nitrous acid into nitric acid. The nitric acid is neutralized with potassium hydroxide to form the product potassium nitrate. No commercial controller exists that can provide hydrogen peroxide in the concentration range of 0.5 to 5.0 percent.

NASA needed to design and build a controller that could handle the particulate residues known to exist in the oxidizer and distinguish the difference between hydrogen peroxide and the oxides of nitrogen. The controller uses the oxidation of hydrogen peroxide with sodium hypochlorite (bleach) to produce oxygen, then measures the resulting pressure. The pressure is directly proportional to the hydrogen peroxide concentration, and the controller monitors the pressure and adds hydrogen peroxide as required to maintain the required pressure. Other requirements were to integrate the pH controller, level controller and remote control of the system from the operations control panel.

For more information, contact Tom Gould at Kennedy Space Center. 407/867-6238, 407/867-2050, *Thomas.Gould-1@kmail.ksc.nasa.gov* Please mention you read about it in *Innovation.*

Promising New Thermal Study Spinoffs

ENVIRONMENTAL PLANNING FOR THE 2002 Olympic Games, strategies to reduce ozone levels, focused tree-planting programs for cooling cities and the identification of materials for cooler building roofs are early spinoffs from a NASA urban study just concluded in three U.S. cities. These new efforts of the Urban Heat Island Pilot Project (UHIPP) also could mean decreased health problems from heat stress and lower utility bills from less overworked air conditioners, even after sunset.

A NASA Lear 23 jet carried a film camera that provided visible images of hot and cold spots matching known ground objects.

Thermal images such as this one of downtown Baton Rouge are helping city planners plan remedies to the heat island effect in their cities.

Ground teams with airborne and satellite sensors and cameras observed three "pilot" cities: Baton Rouge, Louisiana, on May 18; Sacramento, California, on June 29; and Salt Lake City, Utah, July 13 and September 15 (a second flight because of instrument problems on the first). Several other U.S. cities participated through ground-based and satellite observations. Atlanta was studied in May 1997.

A thermal camera took each city's temperature and produced an image that pinpoints each city's "hot spots." The images are being used to study which city surfaces contribute to bubble-like accumulations of hot air, called "urban heat islands."

"This is not a research project," said the study's lead investigator, Dr. Jeff Luvall of Marshall Space Flight Center's Global Hydrology and Climate Center. "We want to get the data out to city planners as soon as possible."

Salt Lake City is using the early results to help plan sites for the 2002 Olympic Games and develop strategies to reduce ground-level ozone concentrations in the Salt Lake City valley. While at high altitudes ozone protects Earth from ultraviolet rays, at ground level it is a powerful and dangerous respiratory irritant found in cities during the summer's hottest months. In Sacramento and Baton Rouge, city planners and tree-planting organizations are using the study to focus their tree-planting programs.

"We are helping the cities incorporate the study into their urban planning," said Maury Estes, an urban planner on Marshall's science team. "By choosing strategic areas in which to plant trees and by encouraging the use of light-colored, reflective building material, we think that the cities can be cooled."

The evaporation of water absorbs a lot of heat. Plants—and trees in particular—evaporate large amounts of water from their leaves. The energy required to evaporate water is taken from the air and from the sunlight intercepted by the leaves, thus cooling the air. Trees are also very effective in shading the ground, thus preventing the heating of the surface by sunlight.

On the other hand, asphalt, concrete and other artificial materials are very effective at absorbing light and re-radiating it as infrared radiation that raises the air's temperature. The science team will continue to analyze the thermal heat information. Luvall and his colleagues and scientists at Lawrence Berkeley National Laboratory are producing computer models so city planners nationwide can better predict the heat island effect for their cities, and then plan remedies.

"The sooner we can get the data out to the people, the quicker they can learn how to deal with it when the calibrated sets are available," Luvall said. "We're starting to develop sample data sets, even though they're not fully calibrated, to get the feel for how to handle it."

The data packages will include public domain software and low-cost geographic information systems to help city planners map the data onto specific parts of their cities. The computer information will swell when the data are fully calibrated to correct for atmospheric interference and apply laboratory optical bench calibrations to the instruments.

NASA's Earth Science Enterprise supports this study. Another purpose of this project is to focus on the Enterprise's efforts to make more near-term economic and societal benefits of Earth science research and data products available to the broader community of public and private users. Also working on the study with Marshall researchers, Lawrence Berkeley and the organizations from the three cities are the U.S. Environmental Protection Agency and the U.S. Department of Energy.

For more information, contact Dr. Jeff Luvall or Tim Tyson at the Global Hydrology and Climate Center, Marshall Space Flight Center. 256/922-5886, *jeff.luvall@msfc.nasa.gov* or *Tim.Tyson@msfc.nasa.gov* Please mention you read about it in *Innovation.*

NASA Developing "Real-Time" Device for Quicker Diagnosis

A NASA-STANFORD UNIVERSITY TEAM IS IN the preliminary stages of developing a smart probe that can be used for breast cancer detection and analysis. The probe is designed to "see" a lump, determine whether it is cancerous by its features and then quickly predict how the disease may progress. Researchers say surgeons may be able to insert the computerized tool's needle-like tip into breast lumps to make instant diagnoses and long-term cancer predictions.

"This device will permit us to make real-time, detailed interpretations of breast tissue at the tip of the needle," said Robert Mah, Ph.D., biomedical engineering. Mah works in the Neuroengineering Laboratory at Ames Research Center, Moffett Field, California. "The instrument may allow health care providers to make expert, accurate diagnoses as well as to suggest proper, individualized treatment, even in remote areas," Mah said.

"To enable the instrument to recognize cancer and predict its progress, we use special neural net software that is trained and learns from experience," Mah added. Scientists can teach the breast cancer diagnosis device to predict how aggressive the disease may be. "The computer software uses pattern recognition to look for tell-tale characteristics of the lump," Mah said.

"We hope to use this device not only to detect cancer, but to understand the nature of an individual cancer," said Dr. Stefanie Jeffrey, assistant professor of surgery and chief of breast surgery at Stanford University School of Medicine in Stanford, California. "This information may help us determine the distinctive features of a malignancy and how the disease may progress. More knowledge about the cancer may guide us to better individualizing treatment."

Jeffrey and Mah, working together to develop the new device, predict that once laboratory tests have been completed, testing the smart probe device on human beings could begin as early as 1999. "Ultrasound will help guide the doctor to properly insert the smart probe into a breast lump," said Dr. Robyn Birdwell, assistant professor of radiology, Breast Imaging Section at Stanford University.

Dr. Robert Mah with the smart probe being developed to detect cancer.

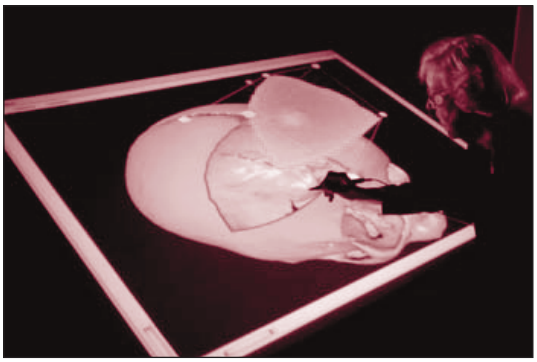
The breast cancer tool is a spinoff from a computerized robotic brain surgery "assistant" that was previously developed by Mah and neurosurgeon Dr. Russell Andrews. The larger brain surgery device is a simple robot that can "learn" the physical characteristics of the brain and may soon give surgeons finer control of surgical instruments during delicate brain operations.

For more information, contact Dr. Robert W. Mah at Ames Research Center. 650/604-6044, 650/604-3594, *rmah@mail.arc.nasa.gov*
Please mention you read about it in *Innovation.*

Virtual Scalpel Improves Surgical Outcomes

A "SOFTWARE SCALPEL," COMBINED WITH clear, accurate, three-dimensional (3-D) images of the human head, is helping doctors practice reconstructive surgery and visualize the outcome more accurately. Using the new Virtual Surgery Cutting Tool software, a physician wearing 3-D glasses can see an image of a patient's head from all angles on a computer monitor or on the surface of a large "immersive virtual reality workbench." Virtual reality is a computer-created environment that simulates real-life situations.

A surgeon uses a computer mouse to mark the incision location, asks the computer to "cut" bone and gets an image of what the result will be in a



(Left) A "software scalpel" used with clear, accurate three-dimensional (3-D) images made from a series of scans of the human head will help doctors practice reconstructive surgery and better predict the outcome.

(Right) A physician wearing 3-D glasses can see an image of a patient's head from all angles on a computer monitor to guide the virtual scalpel in a computer-created environment that simulates a real-life situation.

real operation. The doctor can then remove the simulated piece of bone or can place it at a new angle or in a new position.

"Because some patients have severe injury to the head or diseases such as cancer, there are times when physicians must rebuild a person's head or face," said Dr. Muriel Ross of NASA's Ames Research Center, Moffett Field, California. Ross is director of the Ames Center for Bioinformatics, which uses computer technology to improve medical practices. Additions to the scalpel software would allow doctors to "snap" a face back onto the 3-D image of the skull after a simulated operation, she said, so the doctor and patient can get a better idea of how the face will look after the actual surgery.

In the technique, a series of computed tomography (CT) scans are combined to make the 3-D image of any part of the body, using Reconstruction of Serial Sections (ROSS) software previously developed by researchers at the Ames Center for Bioinformatics. The team also combined features of the ROSS software and the CT scan version to reconstruct a breast tumor from magnetic resonance images. The team wants to work with both mastectomy patients requiring breast reconstruction and children needing reconstructive surgery to correct head and face deformities.

Eventually, software systems could be used in other medical specialties or surgical procedures. The Ames bioinformatics team is working on a variety of virtual reality computer tools to aid in complex reconstructive surgery and other procedures.

The NASA Center for Bioinformatics at Ames is part of a larger national Biocomputation Center established by NASA and Stanford University, Palo Alto, California. "The new center is a national resource to further the use of virtual reality in medicine," Ross said.

Surgeons can use the big-screen workbench, special gloves, computer tracking wands and other devices to manipulate 3-D computer images of patients. A digital library of computerized "virtual patients" will be created that physicians can use to share information about uncommon procedures, according to researchers. Virtual reality is expected to continue allowing surgeons to rehearse numerous complex procedures before operations and to eventually be used as a powerful teaching tool for medical students.

For more information, contact Dr. Muriel Ross at Ames Research Center. 650/604-4804, 650/604-3954, *mross@mail.arc.nasa.gov*
Please mention you read about it in *Innovation.*

Futuristic Technology Helps Preserve Past

A NASA INFRARED CAMERA DEVELOPED TO explore Mars will assist the Smithsonian Institution in its three-year project to preserve the Star-Spangled Banner. The camera, built at NASA's Goddard Space Flight Center in Greenbelt, Maryland, is being used to take images of the historic flag in infrared light to help preservationists identify deteriorated and soiled areas not obvious to the human eye. The camera, called the Acousto-Optic Imaging Spectrometer (AImS), was developed by Dr. David Glenar at Goddard.

The flag is considered a national treasure from the War of 1812. Despite receiving extra special care at the Smithsonian's National Museum of American History, the flag is deteriorating from decades of exposure to light, air pollution and temperature fluctuations.

"It gives me a feeling of great pride that a camera we developed to explore other planets is now exploring this historic artifact," said Dr. John Hillman, the lead person of the camera group at Goddard and NASA's representative on the Smithsonian team.

The AImS was selected because of its special ability to make an image with reflected infrared light. A typical infrared camera relies on thermal infrared, which is light emitted by an object from its heat, but these cameras cannot identify contaminants on the flag because they are the same temperature as the flag itself.

Infrared light is invisible to the human eye, lying beyond the red end of the visible portion of the electromagnetic spectrum. A spectrometer in the camera will be used to separate the light and reveal its component wavelengths, similar to the way a prism separates visible light into a rainbow of colors.

Nearly 72 separate images were taken and pieced together using a computer to create a mosaic of the massive flag, which is 30 feet wide and 34 feet long. Each image takes approximately 25 minutes to make and is composed of 200 infrared wavelengths, or colors.

"Wool is the major component in the surface composition of the flag, and contaminants found on the surface of wool reflect infrared light differently than wool itself," Hillman explained. "With the AImS, we can identify where these differences are located on the flag. Moisture is of particular concern because, in the presence of light, it causes a chemical reaction that deteriorates wool."

The AImS team is developing a demonstration camera for the Mars Instrument Development Program funded by NASA Headquarters. Under this program, a camera using AImS technology could be a candidate for use on robotic Mars lander missions in 2005 and beyond. The camera would be used to determine the mineral composition of Martian rocks.

The camera also can be used to explore the invisible world here on Earth. A cooperative agreement to use AImS in skin cancer research is in place among Goddard, Swales and Associates, Inc., and the Georgetown University Medical Center's Department of Dermatology.

For more information, contact Bill Steigerwald at Goddard Space Flight Center. 301/286-5017, *wsteiger@pop100.gsfc.nasa.gov* Please mention you read about it in *Innovation.*

SENSORS LEAD TO NEW USES

The Commercial Remote Sensing program office at NASA's Stennis Space Center in southern Mississippi has selected 10 projects that could lead to new commercial uses of advanced sensors. The projects are being developed through the Earth Observations Commercial Applications Program-Hyperspectral (EOCAP-Hyperspectral). EOCAP responds to known buyer needs by collaborating with commercial firms to develop enhanced geographic information products, incorporating advanced remote sensing and associated technologies.

Historically, the program has emphasized product development from a technical perspective. The program's new direction is to match market knowledge with technical capability to guide product development based on customers' needs and to expand marketplace acceptance and the use of remote-sensing technology. The commercial role of Stennis is to provide financial and technical support to companies for two to three years in areas of remote-sensing activities in which there is substantial market risk in matching science and technology with commercial demand. The projects support technical, market and business innovation to develop new products or services that help emerging domestic and international markets.

The selection of companies is done through proposals, with emphasis placed on strength in business, marketing and product advisory board resources, as well as each company's financial commitments to the projects. Those selected include Eastman Kodak of New York, the U.S. Department of Agriculture in Maryland, Yellowstone Ecosystem Studies in Montana, Boeing Information, Space and Defense Systems in Washington, MTL Systems Inc. in Ohio, Spectral International in Colorado, Applied Analysis in Massachusetts and Cal State-Monterey Bay, GDE Systems, Inc. and Opto Knowledge Systems, Inc., all of California.

For more information, contact Lanee Cooksey at Stennis Space Center. 228/688-3341, 228/688-1094, *Lanee.Cooksey@ssc.nasa.gov* Please mention you read about it in *Innovation.*

Progressive Efforts in the Light Plane Industry

THE ADVANCED GENERAL AVIATION TRANSPORT Experiments (AGATE) consortium and the NASA General Aviation Propulsion (GAP) program are reporting impressive progress, according to leaders of this government-industry effort to revitalize the U.S. light airplane industry. "These accomplishments are laying the foundation for a small aircraft transportation system that will make personal air travel for business or pleasure a safe, affordable transportation alternative," said Michael B. Mann, NASA's Deputy Associate Administrator for Aero-Space Technology.

Logo for the Advanced General Aviation Transport Experiments (AGATE) consortium.

"Newly developing technologies and procedures are allowing us to move from the research stage to practical use. Even the challenging task of developing a lightweight, affordable jet engine for personal airplanes is coming along quickly through NASA's GAP program," Mann said at a joint NASA, Federal Aviation Administration (FAA) and U.S. industry news briefing held at the recent AirVenture '98, the Experimental Aircraft Association (EAA) annual Fly-In and Convention in Oshkosh, Wisconsin. Anne Harlan, the FAA's Director of the William J. Hughes Technical Center in Atlantic City, New Jersey, also participated in the briefing.

The following are brief descriptions of the accomplishments.

AGATE-Equipped Airplanes Coming to Market

The first two production airplanes to offer extensive AGATE technology are being introduced, with customer deliveries expected to begin after the FAA flight certification to be done by year's end. The Cirrus SR20, produced by Cirrus Design Corp. of Duluth, Minnesota, and the Lancair Columbia 300, produced by Lancair International Inc. of Redmond Bend, Oregon, boast of value, performance, comfort and safety.

AGATE technology contributes to the ease of operation of these two pioneering airplanes through single-lever power control and multifunction display of satellite navigation and airport information. The display technology will also handle graphical display of real-time weather, terrain and digital air-to-ground communications when available in the near future. Other AGATE technologies reflected in these new airplanes include advanced lightweight and aerodynamically efficient composite materials (graphite-epoxy, for example). AGATE safety advances are seen in energy-absorbing structures and improved safety harness systems that improve crashworthiness.

New Process Promising up to $1 Million Savings per New Airplane

The time and costs of certifying materials for new single-engine airplane designs will be dramatically reduced with the adoption of an AGATE-developed certification process. The process promises to cut materials certification for a new design to six months and $30,000—it was two years and a cost range of $600,000 to $1 million. The National Institute for Aviation Research at Wichita State University, Wichita, Kansas, is conducting research to validate the overall process to meet FAA certification standards. The idea is that the AGATE consortium will pool resources to spread the costs of initial research and certification for each material of interest. The data will go into a handbook, specifying the exact process to be followed to receive a speedy certification from the FAA. The first two aircraft to make use of the new process are the Cirrus SR20 and Lancair Columbia 300, mentioned above. They will be the first composite material, four-seat, AGATE-type airplanes to be certified in the United States.

First Pilot Graduating From Streamlined Training Course

The first student has successfully completed a unified flight training curriculum that earned her both a visual and an instrument pilot rating, while saving training time and expenditures. Embry-Riddle Aeronautical University, Melbourne, Florida, administered the AGATE-developed curriculum, which simultaneously trains pilots in visual flight rules and instrument flight rules at significant time and cost savings over traditional methods, which call for separate courses for separate ratings. The national average for receiving a basic private pilot license is approximately 72 hours of

in-flight training over nine months. This is followed by instrument training of 104 hours over an additional nine months.

The Embry-Riddle student completed the equivalent training with a 29-percent savings in ground and flight training, a 20-percent savings in cost and an 83-percent savings in total elapsed time. NASA (through the AGATE program), Embry-Riddle and the FAA Flight Standards District Office in Orlando, Florida, support the new training curriculum.

Flight Tests Proving Cockpit Technologies

The results from two series of ongoing flight experiments are expected to have a major impact on the standards that will be set for operating general aviation airplanes in the future. The AGATE experiments are validating advanced navigation and communications technologies developed to revolutionize how light airplane pilots interact with real-time weather and flight data information. A Cessna T210 has been test-flown since December 1997 to learn more about the display and use of real-time weather in the cockpit. The preliminary results indicate that the use of advanced cockpit weather displays reduces pilot activity while increasing the pilot's ability to accurately and safely navigate around hazardous weather.

"THESE ACCOMPLISHMENTS ARE LAYING THE FOUNDATION FOR A SMALL AIRCRAFT TRANSPORTATION SYSTEM THAT WILL MAKE PERSONAL AIR TRAVEL FOR BUSINESS OR PLEASURE A SAFE, AFFORDABLE TRANSPORTATION ALTERNATIVE."

A Raytheon Bonanza has been test-flown since January 1998 to assess the operational capabilities of digital datalinks. The results of this powerful new cockpit tool are encouraging. The potential applications are numerous, including the present test and evaluation of three attitude and heading reference systems expected to significantly enhance the pilot's awareness of his or her airplane's position and flight heading. Future plans for the Bonanza test airplane include the integration and demonstration of all AGATE technologies in a single cockpit.

First Statewide Digital Datalink Providing Real-Time Weather

Virginia has inaugurated the nation's first statewide application of aviation digital datalink technology, establishing a public-private partnership that will set the pace for its introduction to other states in an effort to form a national system that may someday be global. At a ceremony last July in the state capital in Richmond, Virginia Secretary of Transportation Shirley J. Ybarra praised AGATE member ARNAV Systems Inc. of Puyallup, Washington, the Small Aircraft Manufacturers Association and NASA's Langley Research Center for the successful partnership. Ybarra said that the extension of the AGATE technology "will provide small business with safe, efficient and secure all-weather air transportation to urban and rural communities all over the country."

Reducing the Cost of Lightning Protection

AGATE members are working with Lightning Technology, Inc., Pittsfield, Massachusetts, to reduce the cost of lightning protection for small airplanes from the current $5,000 per airplane to $500 or less by next year. This ambitious goal is part of the AGATE effort to make future single-engine airplanes more affordable to more people. Lightning does not strike small aircraft often, but when it does, it can cause significant damage to nonconducting components and digital cockpit systems.

The company is evaluating airplane surface treatments, such as low-cost lightweight metal meshes embedded in the advanced fiberglass-epoxy composite materials increasingly used in small airplane structures. Tests have applied simulated lightning effects (up to 200,000 amperes of current) to small "coupons" representing airplane skin and structure.

Propulsion Research Filling the Gap

Two years after NASA's Lewis Research Center unveiled the General Aviation Propulsion (GAP) program, industry teams are reporting substantial progress in developing forerunners of the next generation of general aviation light aircraft engines. The development of the following engines is on schedule for flight demonstration at EAA's AirVenture '00:

- *New Piston Engine at Half the Price*—An industry team led by Teledyne Continental Motors, Mobile, Alabama, has designed and built a

highly advanced 200-horsepower compression ignition engine, now going through a series of tests. The first aircraft installation is set sometime in late 1999. The engine will use jet fuel and is designed to be priced at half the cost of current engines. Careful design consideration has been given to making this engine the smoothest and quietest piston engine to have ever flown in a general aviation aircraft. The design is now becoming reality.

- *New Turbine Engine Promises High Performance at Competitive Price*—Williams International of Walled Lake, Michigan, and its industry team have designed a radically new turbofan engine, which will make turbine engines affordable for small general aviation aircraft. This engine, known as the FJX-2, is a high-bypass-ratio turbofan that will produce 700 pounds of thrust while weighing less than 100 pounds. The FJX-2 is designed to provide excellent performance while being price competitive with piston engines. Turbine engines are known for their good performance and quiet smooth operation; however, they have only been used in the top-of-the-line general aviation aircraft because they are very expensive. A turbine engine propulsion system can cost more than an entire airplane. Engine component testing has progressed at a good pace. The first full engine was scheduled to be completed and ready for testing sometime in December 1998.

For more information, contact Leo Burkardt at Lewis Research Center. 216/977-7021, 216/977-7008, *leo.burkardt@ lerc.nasa.gov* Or contact H. Keith Henry at Langley Research Center. 757/864-6120, 757/864-8199, *h.k.henry@larc.nasa.gov* Please mention you read about it in *Innovation.*

TESTS CONTINUE TO EXPAND SPACE TRAVEL

NASA has successfully completed two years of testing new, radical air-breathing rocket engines that could change the future of space travel, lowering the cost and making it affordable and available to everyone, from business travelers to tourists. NASA and its industry partners have successfully ground-tested rocket engines that "breathe" oxygen from the air and are planning to conduct flight tests in the future. The spacecraft would be completely reusable, take off and land at airport runways and be ready to fly again within days.

Test firing of an air-breathing rocket at a small aerospace company in New York.

"Air-breathing rocket engine technologies have the potential of opening the space frontier to ordinary folks," said Uwe Hueter, manager of NASA's Advanced Reusable Technologies project at Marshall Space Flight Center in Huntsville, Alabama. An air-breathing rocket engine inhales atmospheric oxygen for about half the flight. It does not have to store all the oxygen gas onboard; therefore, at takeoff, an air-breathing rocket is carrying less fuel than a conventional rocket. Getting off the ground is the most expensive part of any mission. Weight reduction decreases cost significantly.

Specially designed rockets boost the air-breathing engine's performance by 15 percent over conventional rockets at takeoff. When aircraft velocity reaches twice the speed of sound, the rockets are turned off, and the engine totally relies on atmospheric oxygen to burn the hydrogen fuel. As the vehicle's speed increases to about ten times the speed of sound, the rocket-powered system takes over to propel the vehicle into orbit.

For more information, contact Uwe Hueter at Marshall Space Flight Center. 256/544-8492, *uwe.hueter@msf.nasa.gov* Please mention you read about it in *Innovation.*

Flight Software to Yield Huge Savings

ALMOST A BILLION DOLLARS COULD BE SAVED annually when award-winning air traffic control software developed by NASA is in use nationwide at major airports and en route centers. The Federal Aviation Administration (FAA) has chosen the software for implementation at major airports and estimated its use could save as much as $800 million per year.

"The air traffic software is in daily use at Dallas-Fort Worth, the world's busiest airport," said Heinz Erzberger, senior scientist for air traffic management at Ames Research Center, Moffett Field, California. "The software saves an average of two minutes per flight, saving money for airlines and passengers."

Officially called "Center TRACON Automation System Software," or CTAS, it includes two software tools for managing air traffic. They are the Traffic Management Advisor and the Final Approach Spacing Tool that assist air traffic controllers with airplanes en route and at terminals. TRACON stands for terminal radar approach control.

The Traffic Management Advisor helps traffic managers establish a flow rate of air traffic that closely matches the capacity of an airport. The Final Approach Spacing Tool provides suggested landing sequences and runway assignments to minimize delays, and it increases the landing rate by about 10 percent during critical traffic rushes. An advanced version of the spacing tool, now being developed, will provide speed and heading advisories to help controllers space air traffic accurately on final approach, further increasing capacity.

"The cost to the FAA of implementing the first two tools is about $600 million over an eight-year period, an effort that began in 1996," said Erzberger. He was the originator of the CTAS automation concept. CTAS is to be installed in 22 major airports and 15 en route centers. These centers control air traffic above 10,000 feet.

In 1991, the CTAS project began at Ames. An early version of the system is in daily use at Denver, Los Angeles, Hartsfield-Atlanta and Miami international airports. The CTAS software, developed under the direction of Michelle Eshow, CTAS software development group leader at Ames, was recently named co-winner of NASA's 1998 Software of the Year Award.

"CTAS is like a 'windows' computer environment. CTAS enables the addition of many more air traffic controller tools beyond the first two," Erzberger explained. One new tool now being developed is the Descent Advisor. "It improves fuel efficiency of aircraft descents into large airports," Erzberger said.

CTAS tools are designed to be "human centered" because the tools advise controllers, who retain full control over decisions. CTAS also adapts to controller actions and unplanned events. It refreshes trajectories and advisories every 4 to 12 seconds with each radar update as well as with each controller input.

For more information, contact Heinz Erzberger at Ames Research Center. 650/604-5425, herzberger@mail.arc.nasa.gov Please mention you read about it in *Innovation.*

Nationwide use of award-winning NASA air traffic control software could save nearly a billion dollars annually.

Cryogel™ Blankets Space and Commercial Applications

A NEW ENGLAND COMPANY, USING A NASA space age insulation material, has developed a new superinsulating blanket with numerous commercial and space applications. Using aerogel, a material with exceptional insulating properties, Aspen Systems Inc. of Marlborough, Massachusetts, developed a blanket with an insulation factor higher than any other engineering material. The aerogel helped Aspen reduce the cost of operating and maintaining cryogenic systems, as well as make possible a variety of new commercial applications to benefit consumers.

The current primary market for the Cryogel™ blanket is the cryogenic insulation market, according to Kang Lee, Aspen Systems president, but potential markets are many. They include: insulation for offshore oil well underwater pipelines; refrigerators in luxury yachts; shipping containers; household freezers, refrigerators and ovens; spacecraft to guard against deep space cold and the refrigeration and heating of containers within the spacecraft.

COMMERCIAL SALES OF CRYOGEL™ ARE LESS THAN $100,000 PER YEAR.

Additional market possibilities are: refractory insulation for automotive firewalls, floorboards, exhaust systems, race cars and guidance airfoils in rockets; high-efficiency filtering media for heating, ventilating and air conditioning (HVAC) systems, respirators and automotive air intake; high-surface-area catalysts; noise suppression honeycomb structural panels for aircraft and acoustic damping insulation for buildings, process equipment, head phones, vehicle head liners and combustion furnaces. There is even a potential market in skylights and translucent panels for buildings, Lee added.

Potential space applications include the Reusable Launch Vehicle, Space Shuttle upgrades and interplanetary propulsion and life support equipment. Aerogel is also being tested for the Space Shuttle upgrade to a nontoxic orbital maneuvering system, which includes the need for a high-performance insulation of liquid oxygen tanks and feedlines.

Working under a Small Business Innovation Research (SBIR) contract with Kennedy Space Center, Aspen Systems responded to NASA's need for an aerogel-based cryogenic insulation system with extremely low thermal conductivity that is flexible, durable and easy to use. The Space Shuttle program at Kennedy is particularly interested in the superinsulation because of the large amounts of cryogenic fluids consumed during many phases of the launch processing operations.

NASA engineer James Fesmire explained that prototype superinsulation systems are currently being field-tested at Kennedy. The basic form of the system is a blanket composed of aerogel-based composites and radiation shield layers. The final product can be a blanket, sheet or clamshell unit, depending on the application.

For the cryogenic insulation market, Cryogel™ will be cheaper than the existing competing technology, multilayer insulation. Compared to multilayer insulation, aerogel allows a two- to three-order-of-magnitude reduction in the insulation jacket's required vacuum. This translates into significantly smaller vacuum stations, rendering reduced operating and maintenance costs.

For the refrigeration market, Cryogel™ will allow thinner refrigerator walls, which will increase the refrigerated volume of the system. For the translucent panels and skylight market, the product will allow significant light transmissions with a fraction of the heat loss associated with competing technologies.

Aspen Systems, founded in 1984 to provide its clients with research and development services, currently has a small pilot manufacturing plant. Commercial sales of Cryogel™ are less than $100,000 per year, Lee said. Aspen Systems plans to build an interim pilot plant to increase its production rate twenty-fold and prove the practicality of scaling up its concept.

Aspen sold or sent samples of its aerogel to organizations to help identify new markets. The result has been a remarkable realization of the vast potential of the company's aerogel products. Although the exact financial size of these markets has not been identified, they nonetheless represent potentially lucrative commercial markets.

For more information, contact Tom Gould at Kennedy Space Center. 407/867-6238, 407/867-2050, *Thomas.Gould-1@kmail.ksc.nasa.gov* Please mention you read about it in *Innovation.*

Shuttle Technology Reduces Manufacturing Defects

BY COMMERCIALIZING AN ENVIRONMENTAL fallout monitor originally designed to protect Space Shuttle payloads from contamination, NASA's technology transfer program is helping a Florida company provide a means for manufacturers to reduce costs and the number of defects in the manufacturing process. Technical Applications Unlimited (TAU), Inc., Cape Canaveral, Florida, is marketing the TAU-N100A, an economical contamination monitoring alternative for applications involving clean rooms, semiconductor manufacturing, pharmaceutical production, spacecraft processing, food processing, heating, ventilating and air conditioning (HVAC) performance assessment and area motion/activity detection. The company, a member of the Florida/NASA Business Incubation Center, received a patent license from NASA at Kennedy Space Center for the Particle Fallout/Activity Sensor, now called the Real Time Optical Fallout Monitor (OFM).

"NASA has made it possible for TAU to get off the ground with a high-technology product that would have taken years and many more resources than a typical small business start-up company can make available," company president John Horan said. "We feel like TAU will be able to compete with the instrumentation industry leaders as a result of this boost from NASA."

TAU's research shows approximately 68,000 clean room facilities in the United States. Horan said he sees a large potential market with mounting concern over the possible hazards of airborne microparticles present in our ordinary living and working environments.

The OFM is a portable, optoelectronic instrument that uses a light-scattering technique to measure the accumulation of particles. It is compact, measuring 17.5 by 15.5 by 14.5 centimeters, and weighs only 1.5 kilograms. The monitor detects a single particle as small as 10 microns. Fallout accumulation measurements can be displayed on the front panel and/or downloaded for remote monitoring or analysis in real time.

The OFM technology has been improved during the commercialization process. TAU introduced temperature compensation circuitry and electromagnetic interference shielding, which improves the sensitivity and stability of the instrument.

TAU has sold OFMs to two major companies to date, and several other companies have expressed interest. A leading computer chip manufacturer purchased units to detect environmental contamination during production to reduce the number of defective chips, and a major aerospace/defense contractor has acquired units to monitor cleanliness during the integration of its next payload with the Titan IV rocket.

Major manufacturers, including a dominant California biopharmaceutical maker, are evaluating the OFM as an aid to assess cleanliness in manufacturing and processing environments, ultimately reducing defects caused by environmental contaminants. Lawrence Livermore National Laboratory has expressed interest in the OFM to help detect environmental fallout in various experimental nuclear processes.

NASA developed the OFM to accurately detect and monitor the accumulation of potentially damaging environmental contamination (such as dust, fibers or condensing vapor) on sensitive payload

The TAU-N100A is the ultimate instrument for cost-effective, real-time, qualitative fallout analysis for a number of commercial applications.

components in real time. The OFM eliminates both the need for laboratory technicians to process witness plate samples and the miscellaneous labor to collect and transport the samples and generate the laboratory reports. The OFM lowers the cost of the capital equipment necessary to provide the particle fallout contamination monitoring function for up to approximately 20 monitoring sites.

The total quality of facility services is improved by the OFM's ability to identify and react to contamination as it is occurring. This results in lower costs because of the possibility of quickly mitigating potential contamination and increasing the reliability of the manufacturing result.

Time-tagged data available from the OFM provide the ability to associate specific fallout events with the time of occurrence for analytical, substantiation or certification purposes. The OFM eliminates the need to manually count and characterize particles; thus it improves the reliability of contamination measurements that may be caused by the tedious and subjective nature of the analysis process.

For more information, contact Tom Gould at Kennedy Space Center. 407/867-6238, 407/867-2050, *Thomas.Gould-1@kmail.ksc.nasa.gov* Please mention you read about it in *Innovation.*

Commercial Capability Increasing for Launch Processors

COMMAND AND CONTROL TECHNOLOGIES (CCT) Corporation of Titusville, Florida, located in the Florida/NASA Business Incubator, is commercializing software technology based on Kennedy Space Center's spacecraft ground processing program's Control Monitor Unit (CMU). The CMU software and hardware capabilities include processing equipment-test data for calibration and diagnosis, controlling the operation of the equipment in real time, simulating the operation of the equipment and processing large streams of scientific measurement data for the new Space Shuttle Checkout and Launch Control System (CLCS). It was originally developed by NASA and McDonnell Douglas Space & Defense Systems at Kennedy to prepare the International Space Station elements for launch.

Commercial capability for the CLCS is expanding. New long-term commercial applications include a product called the Command and Control Toolkit™ (CCTK). The CCKT includes remote monitoring of mobile operations, such as offshore oil platforms, aeronautical uses and remote land operations using future wireless telecommunications satellite constellations.

INNOVATIVE SMALL BUSINESS PROJECTS SELECTED

NASA has selected 25 research proposals for negotiation of Phase I contract awards for the agency's 1998 Small Business Technology Transfer (STTR) program, with an expected combined award total of nearly $2.5 million. NASA reviewed 130 proposals from small, high-technology businesses across the country for technical merit, feasibility and relevance to NASA research and technology requirements.

The STTR program requires small businesses to conduct cooperative research and development by partnering with a research institution. It is designed to stimulate technological innovation, help small businesses become better qualified to assist NASA in its research and development and increase private commercialization of federally funded research.

The selected firms will be awarded fixed-price contracts valued up to $100,000 each to perform a one-year Phase I feasibility study. Companies that successfully complete the Phase I activities are eligible to compete for Phase II selection the following year. The Phase II award allows for a two-year, fixed-price contract up to $500,000.

The NASA STTR Program Management Office is located at the Goddard Space Flight Center, Greenbelt, Maryland, with executive oversight by NASA's Office of Aero-Space Technology, NASA Headquarters, Washington, D.C. Individual STTR projects are managed by the NASA field centers. A list of companies selected can be found on the web at *http://sbir.nasa.gov*

For more information, contact Dr. Jim Chern at Goddard Space Flight Center. 301/286-5836, 301/286-1646, *Engmin.J.Chern.1@gsfc.nasa.gov* Please mention you read about it in *Innovation.*

Products to facilitate the expanded use of the CLCS at Kennedy are being developed, said CCT president Peter C. Simons. The company's advanced portable payload tester prototype will provide capabilities to demonstrate how Space Shuttle and Reusable Launch Vehicle payloads could be processed. A portable unit capable of being transported to a payload customer site could reduce processing time and cost at the launch site.

"This system will demonstrate the feasibility of using a small mobile system that is compatible with the CLCS to prepare spacecraft for flight," said Simons. "We are concentrating on developing a proof-of-concept demonstration for the upcoming X-34 reusable launch system."

As a key software architect of the CLCS, the company is helping apply its technologies to solve complex subsystem problems. Simons added that a sophisticated application development environment is being created to enable console operators to quickly configure and interconnect advanced tools to create automated sequencers, commanding agents and graphics displays without programming.

CCT and NASA signed a copyright license agreement to commercialize the Kennedy CMU software. The agreement calls for NASA to license the copyrighted CMU software to CCT in return for royalties and other considerations. CCT is the first company to license NASA's CMU software. The agreement grants CCT exclusive rights to sell the program to new commercial customers in the U.S. launch vehicle industry.

CCT, a member of the Florida/NASA Business Incubation Center, is the only U.S. firm specializing in launch vehicle control systems design and development for spaceports and new launch vehicle programs. The company provides software and maintenance for the control system of the Astronaut Memorial Foundation's Space Mirror, located at the Kennedy Visitor Complex.

For more information, contact Tom Gould at Kennedy Space Center. 407-867-6238, 407/867-2050, *Thomas.Gould-1@kmail.ksc.nasa.gov* Please mention you read about it in *Innovation.*

TECH EAST '98: CONFERENCE HIGHLIGHTS

Tech East '98, recently held in Boston, Massachusetts, brought approximately 7,500 participants together to view such events as Photonics East (the only optics and photonics exhibit in the Northeast), Electronic Imaging (the east coast's premier annual imaging exhibit) and the New England Design and Manufacturing Expo (the first major design engineering exposition in the heart of the New England high-tech corridor, featuring new products and services to help engineers meet their design, prototyping, testing and production challenges). Coupled with these events was the Ninth Annual Technology Transfer Conference—America's premier showcase of new and next-generation technologies available for license and commercial development.

As a part of these activities, the Small Business Tech Expo was held, representing the first annual showcase of resources and technologies to launch new products and partnerships. In seeking financing and investment opportunities, marketing expertise and consulting services, as well as how to tap into the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, small business entrepreneurs were invited to participate in concurrent sessions. These sessions ranged from the basics of proposal writing, financial planning and intellectual property protection to one-on-one sessions with NASA and other Federal SBIR/STTR managers, procurement specialists and participating company representatives. Participants discussed opportunities for funding, subcontracting and partnering to gain strategic insight for moving SBIR technologies to market.

NASA brought its SBIR exhibit, featuring the best of the agency's success stories, was actively engaged in the one-on-one sessions and exhibited for the first time the NASA Small Business Solutions Center. In addition to NASA resources such as the technology commercialization network, the National Science Foundation provided an SBIR Resource Center to assist small high-tech firms in their search for resources and strategic partners for their research and development programs. Conceived by Carl Ray, SBIR/STTR Program Executive at NASA Headquarters, the Solutions Center was one of the most commented-on features of the exposition, according to the organizer of the Small Business Tech Expo, Del DelaBarre. The display featured NASA technologies developed through the SBIR/STTR programs and featured current displays of program opportunities, while virtually serving as a guide to other small business resources at Tech East.

Technology Opportunity Showcase *highlights some unique technologies that NASA has developed and which we believe have strong potential for commercial application. While the descriptions provided here are brief, they should provide enough information to communicate the potential applications of the technology. For more detailed information, contact the person listed. Please mention that you read about it in* Innovation.

Hot NASA Technologies

Thin-Film Heat Flux Sensor

Lewis Research Center is seeking industry partnerships to transfer the process for fabricating thin-film heat flux sensors for both aerospace and nonaerospace applications. The thin-film heat flux sensors can be fabricated as plug-type sensors on the surface of a ceramic material or directly on a part's surface, such as a turbine blade. Heat flux temperatures up to 1,700 degrees Fahrenheit can be measured. The sensor can be fabricated directly onto the part without cutting into the part. They are minimally intrusive in engines, and they are of a small mass so high-frequency measurements can be made. The sensors provide accurate knowledge of heat loading on critical propulsion system components. These sensors can also measure very high heat fluxes—up to 88 Btu/ft^{2}sec. Potential commercial uses include measuring heat flux incident on ceramic engine parts and rocket engine parts, measuring heat flux in automotive engines and aircraft engines, measuring furnace outputs, detecting fires and applying to calorimetry.

For more information, contact Larry Viterna at Lewis Research Center. 216/433-3484, 216/433-5012, *Larry.A.Viterna@lerc.nasa.gov* Please mention you read about it in *Innovation.*

Thermal Switch Disc

Researchers at Johnson Space Center developed the thermal switch disc, a low-cost, positive temperature coefficient resistor that protects battery-powered electronic equipment from the hazards of overheating and short circuiting. It is a solid-state disc made of conductive material, whose resistance changes with temperature to prevent damage to the electrical equipment. Resistance is minimum at normal operating temperatures and maximum at approximately 2,000 degrees Fahrenheit. A circular supporting brace locks the conductive element in place so that it is firmly held between batteries. The switch disc is safe, preventing battery-operated equipment from sparking and fires caused from overheating and short-circuit sparking. The device installs easily, offers simplicity and automatically resets after triggering. Knowledge of the application's voltage and current are the only requirements to select the proper disc. It is cost-effective, both in decreasing unnecessary repair bills and in minimal cost to consumers because only one switch is required per parallel string of batteries, allowing a high degree of protection. The device is ideally suited for use in portable or home electronic equipment and toys, in which one or several batteries are placed in series or parallel, as well as in high-reliability industrial equipment using similar battery arrangements. Typical applications include radios, flashlights, cellular phones and laptop computers.

For more information, contact Monty Coats at the Mid-Continent Technology Transfer Center. 800/472-6785 or 409/845-2907, 409/845-3559, *ted@teexnet.tamu.edu* Please mention you read about it in *Innovation.*

Torque Wrench Adapter

Kennedy Space Center seeks to transfer the Torque Wrench Adapter for Confined Spaces technology to private industry and the general public for use in industrial applications to provide accuracy while torquing spanner nuts in hard-to-reach places. This adapter, used with a standard torque wrench, was developed for use in tightening electrical cable retainer nuts on the Space Shuttle's Solid Rocket Boosters at Kennedy. The boosters' cable connections are in very confined areas, and no known devices existed for properly torquing the retainer nuts. This tool is simple and reliable, requires no maintenance and could last indefinitely with minimum care and normal usage. It provides time savings in disconnect/connect procedures for the troubleshooting of connectors in confined areas. Potential commercial uses are in the aerospace industry, commercial airlines, telephone companies, communications cable companies, the computer industry, the automobile industry and the electronic industry. Currently, two different sizes of the adapter (a two-inch and a two-and-a-half-inch) have been made.

For more information, contact the Technology Programs and Commercialization Office at Kennedy Space Center. 407/867-6200, 407/867-2050, *Technology.Transfer@ksc.nasa.gov* Please mention you read about it in *Innovation.*

NCTN DIRECTORY

Moving Forward

NASA Field Centers

Ames Research Center
Selected technological strengths are Information Technologies, Aerospace Systems, Autonomous Systems for Space Flight, Computational Fluid Dynamics and Aviation Operations.

Carolina Blake (Acting)
Ames Research Center
Moffett Field, California 94035-1000
650/604-0893
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths are Aerodynamics, Aeronautics Flight Testing, Aeropropulsion, Flight Systems, Thermal Testing and Integrated Systems Test and Validation.

Eugene (Lee) Duke
Dryden Flight Research Center
Edwards, California 93523-0273
805/258-3802
lee.duke@dfrc.nasa.gov

Goddard Space Flight Center
Selected technological strengths are Earth and Planetary Science Missions, LIDAR, Cryogenic Systems, Tracking, Telemetry, Command, Optics and Sensors/Detectors.

George Alcorn
Goddard Space Flight Center
Greenbelt, Maryland 20771
301/286-5810
george.e.alcorn.1@gsfc.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths are Deep and Near Space Mission Engineering and Operations, Microspacecraft, Space Communications, Remote and In-Situ Sensing, Microdevices, Robotics, and Autonomous Systems.

Merle McKenzie
Jet Propulsion Laboratory
Pasadena, California 91109
818/354-2577
merle.mckenzie@jpl.nasa.gov

Johnson Space Center
Selected technological strengths are Life Sciences/Biomedical, Spacecraft Systems, Information Systems, Robotic and Human Space Flight Operations

Henry (Hank) Davis
Johnson Space Center
Houston, Texas 77058
281/483-0474
henry.l.davis@jsc.nasa.gov

Kennedy Space Center
Selected technological strengths are Emissions and Contamination Monitoring, Sensors, Corrosion Protection and Biosciences.

Gale Allen
Kennedy Space Center
Kennedy Space Center,
Florida 32899
407/867-6226
gale.allen-1@kmail.ksc.nasa.gov

Langley Research Center
Selected technological strengths are Aerodynamics, Flight Systems, Materials, Structures, Sensors, Measurements and Information Sciences.

Joe Heyman
Langley Research Center
Hampton, Virginia 23681-0001
757/864-6005
j.s.heyman@larc.nasa.gov

Lewis Research Center
Selected technological strengths are Aeropropulsion, Communications, Energy Technology and High Temperature Materials Research, Microgravity Science and Technology and Instrumentation Control Systems.

Larry Viterna
Lewis Research Center
Cleveland, Ohio 44135
216/433-3484
Larry.A.Viterna@lerc.nasa.gov

Marshall Space Flight Center
Selected technological strengths are Materials, Manufacturing, Nondestructive Evaluation, Biotechnology, Space Propulsion, Controls and Dynamics, Structures and Microgravity Processing.

Sally Little
Marshall Space Flight Center
Huntsville, Alabama 35812
256/544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths are Propulsion Systems, Test/Monitoring, Remote Sensing and Nonintrusive Instrumentation.

Kirk Sharp
Stennis Space Center
Stennis Space Center, Mississippi
39529-6000
228/688-1914
kirk.sharp@ssc.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Joseph C. Boeddeker
Ames Technology Commercialization Center
San Jose, CA
408/557-6789

Lyn Stabler (Acting)
Mississippi Enterprise for Technology
Stennis Space Center, MS
228/688-3144

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
216/586-3888

Thomas G. Rainey
Florida/NASA Business Incubation Center
Titusville, FL
407/383-5200

Judy Johncox
University of Houston/NASA Technology Center
Houston, TX
713/743-0451

Kirk Wiles
Business Technology Development Center
Huntsville, AL
256/704-6000

Kathleen Weiss
Maryland Economic Development Corp.
Greenbelt, MD
301/528-1546

Van Garner
California State Polytechnic University–Pomona
Pomona, CA
909/869-2276

Catherine Renault
Hampton Roads Technology Incubator
Hampton, VA
757/689-3024

Small Business Programs

Carl Ray
NASA Headquarters
Small Business Innovation Research Program (SBIR/STTR)
202/358-4652
cray@hq. nasa.gov

Paul Mexcur
Goddard Space Flight Center
Small Business Technology Transfer (SBIR/STTR)
301/286-8888
paul.mexcur@pop700.gsfc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the RTTC nearest you, call 800/642-2872.

Ken Dozier
Far West Technology Transfer Center
University of Southern California
213/743-2353

Dr. William Gasko
Center for Technology Commercialization
508/870-0042

J. Ronald Thornton
Southern Technology Applications Center
University of Florida
352/294-7822

Gary F. Sera
Mid-Continent Technology Transfer Center
Texas A&M University
409/845-8762

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
412/383-2500

Christopher Coburn
Great Lakes Industrial Technology Center
Battelle Memorial Institute
440/734-0094

Joseph P. Allen
National Technology Transfer Center
Wheeling Jesuit University
800/678-6882

Doris Rouse
Research Triangle Institute Technology Applications Team
Research Triangle Park, NC
919/541-6980

NASA ON-LINE

Go to **NASA's Commercial Technology Network (CTN)** on the World Wide Web at ***http://nctn.hq.nasa.gov*** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

Events

Kennedy Space Center will showcase NASA technologies commercialized by Florida businesses January 10, 1999, at North Brevard Public Library, and February 11, 1999, at Central Brevard Public Library. For more information, contact Jim Aliberti at Kennedy's Technology Programs and Commercialization Office. Call 407/867-6224 or e-mail *Jim.Aliberti-1@ksc.nasa.gov*

The Chapman Conference on Atmospheric Science Across the Stratopause will be held April 19–22, 1999, at the Historic Inns of Annapolis, Maryland. Chapman conferences are small, highly focused meetings, sponsored by the American Geophysical Union (AGU), to provide significant time for discussion and interaction. This conference will provide a forum for researchers in stratospheric and mesospheric chemistry, physics and dynamics. The topics of discussion include planetary wave propagation, observations and climatologies of gravity waves and tides, photochemical problems in the stratopause region and atmospheric energetics. For more information, contact the AGU Meetings Dept. Call 202/462-6900 or visit the web site at *www.agu.org/meetings/chapman*

The 1999 Spring Meeting of the American Geophysical Union will be held May 31–June 4, 1999, at the John B. Hynes Convention Center, Boston, Massachusetts. The meeting provides an outstanding opportunity for researchers, teachers, students and consultants to review the latest issues affecting Earth, the planets and their environment in space. For more information, call 800/966-2481 or visit the web site at *www.agu.org*

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